QUEEN'S-RMC FCRC Fuel Cell Research Centre

FUEL CELL RESEARCH CENTRE

Gas Blending System Model FCRCGM-03

User Manual

QUEEN'S - RMC FUEL CELL RESEARCH CENTRE

FCRCGM-03

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System Overview

Four channel gas control and blending.

The FCRCGM-03 is a four channel gas delivery and blending system. This manual details the use, capabilities, specifications and care of the system.

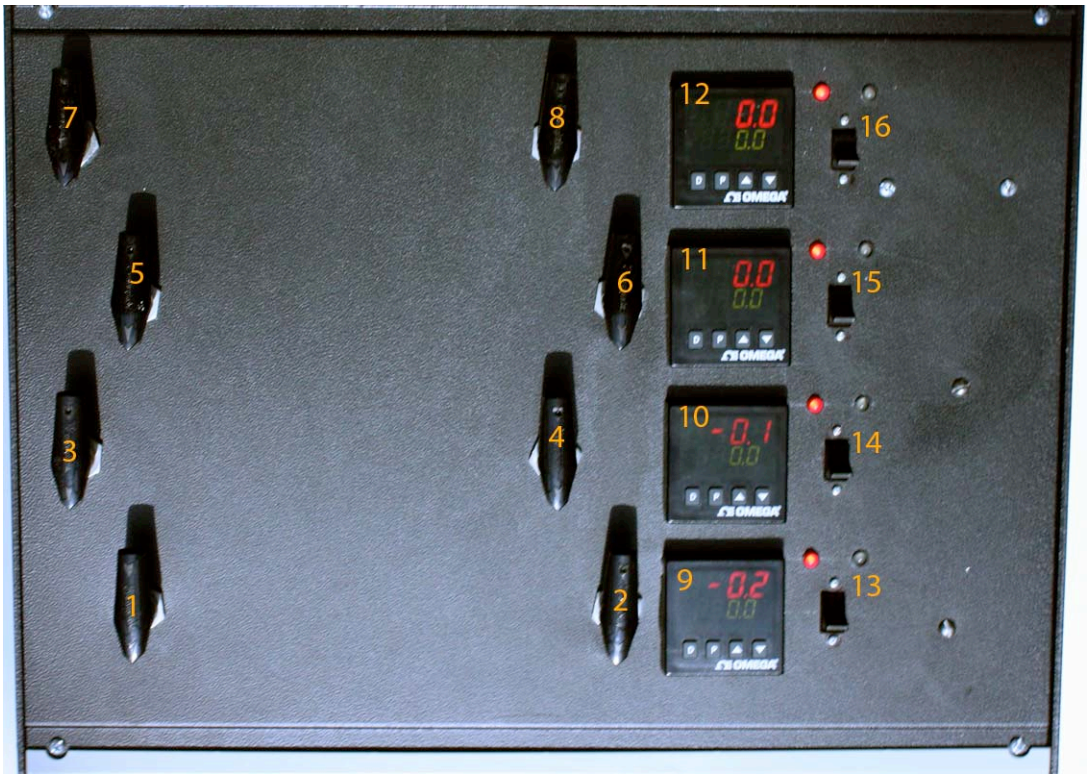
ICON KEY
Valuable information
Safety Information

System Layout

Front

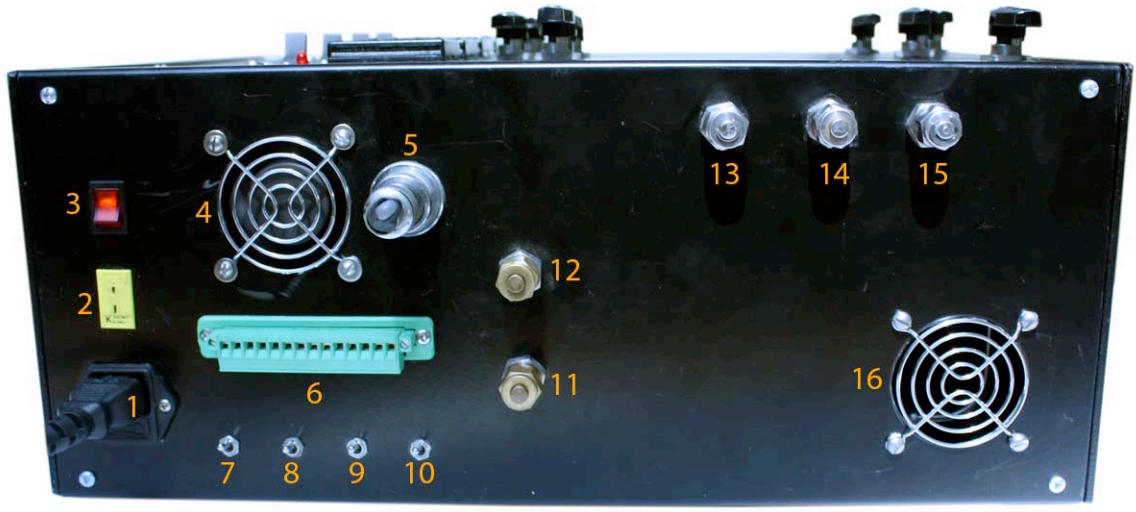
Item	Function
1	Common Inlet
2	MFC 1 Inlet
3	MFC 2 Inlet
4	MFC 3 Inlet
5	MFC 4 Inlet
6	MFC 1 RS-232 data connection
7	MFC 2 RS-232 data connection
8	MFC 3 RS-232 data connection
9	MFC 4 RS-232 data connection
10	E-stop button
11	E-stop reset button and status indicator
12	Temperature limit switch override
13	Temperature limit switch

Top



Item	Function
1	MFC 1 Inlet selection ball valve
2	MFC 1 Outlet selection ball valve
3	MFC 2 Inlet selection ball valve
4	MFC 2 Outlet selection ball valve
5	MFC 3 Inlet selection ball valve
6	MFC 3 Outlet selection ball valve
7	MFC 4 Inlet selection ball valve
8	MFC 4 Outlet selection ball valve
9	MFC 1 Omega process controller
10	MFC 2 Omega process controller
11	MFC 3 Omega process controller
12	MFC 4 Omega process controller
13	MFC 1 Flow override switch and indicators
14	MFC 2 Flow override switch and indicators
15	MFC 3 Flow override switch and indicators
16	MFC 4 Flow override switch and indicators

Back



Item	Function
1	AC power connector
2	Thermocouple input for over-temp shutoff
3	Power switch
4	Cabinet ventilation inlet
5	E-stop extension connector
6	Analog signal connector
7	MFC 1 control switch
8	MFC 2 control switch
9	MFC 3 control switch
10	MFC 4 control switch
11	Mixed gas outlet
12	MFC 4 gas outlet
13	MFC 3 gas outlet
14	MFC 2 gas outlet
15	MFC 1 gas outlet
16	Cabinet ventilation outlet

General

The FCRCGM-03 gas delivery and blending system can be used as a stand-alone unit, or connected to a computer or analog controller for external control. An integrated E-stop circuit allows analog set point control only when applicable safety criteria are met.

Plumbing

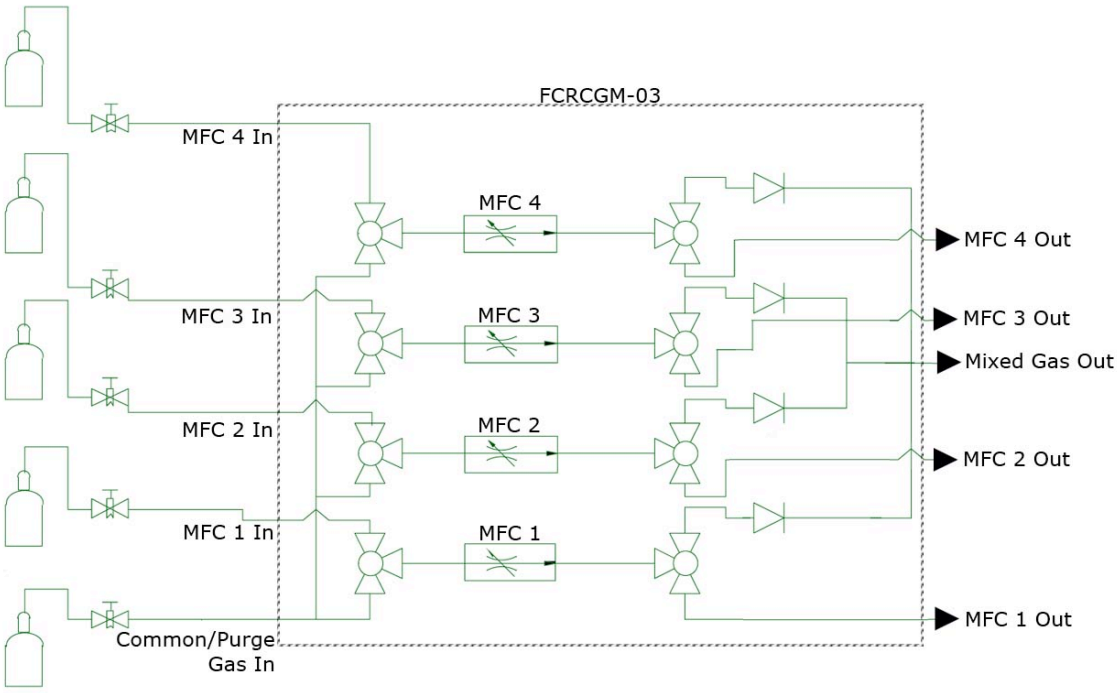
Gas flow through the system is controlled by four Mass Flow Controllers, herein referred to as MFC1, MFC2, MFC3 and MFC4. Refer to the System Specifications section of this manual for the specifications of each MFC.

There are five inlet gas connections at the front of the machine. The first gas input line connects to a manifold available to each of the four mass flow controllers in the system. This port is referred to as the Common inlet. The remaining four gas inlet connections correspond their relative mass flow controllers. The inlet gas to each MFC is selected from either the common manifold or the inlet connection specific to the MFC.

The outlets of the MFC's are in a similar configuration to the inlets. Five outlet ports are located at the back of the system; one outlet for each MFC, and one outlet common to all MFC's used for gas blending.

This configuration is meant to provide versatility in that the each MFC can provide gas blending capability or simply be used to control a single gas flow.

Plumbing Diagram



Controls

The MFC's in the system can be controlled by four methods; manually specifying a set point via the Omega process controllers (local control), an external analog 4-20mA signal, a flow override switch forcing zero or full flow, or RS-232 control using a PC and Bronhorst Flow View or Flow Plot.

Read back of the MFC process value in all modes of control is available in the top section of the Omega process controllers. The MFC process values can also be connected to external devices for data logging etc.

Safety system

An expandable hard-wired safety system is included with the FCRCGM-03. The safety system monitors e-stop trigger devices and halts flow through the MFC's if a problem is detected. There are two on-board e-stop triggers; an e-stop button, and a Watlow temperature switch (used with an external K type thermocouple. The temperature switch can also be bypassed if this control is not applicable to the application.

Additional e-stop devices may be added to the e-stop loop, and a relay e-stop status output is available to external devices.

The system must be out of e-stop in order to flow gases in either local or external analog control. To get the system out of e-stop;

- Ensure all external e-stop devices are in a closed-switch state
- If no external e-stop devices are present, ensure the external e-stop jumper is installed
- If an external thermocouple is connected, ensure the temperature limit override switch is up (not bypassed) and press the Reset button on the Watlow temperature switch
- If no external thermocouple is used, set the temperature limit override switch to the down position to bypass the circuit
- Ensure the red e-stop button is pulled out
- Press the green e-stop reset button. The button should illuminate indicating the system is out of e-stop and ready to control gas flow

☝ **Note: The e-stop circuit is bypassed for MFC's under RS-232 control.**

System Installation

Wiring

Electrical connections to the system are used for e-stop expansion, external gas control and monitoring, and MFC calibration.

External flow control and monitoring

To externally control and monitor gas flow with analog signals, use the 14 pin phoenix connector at the back of the system. External set points to the MFC's are sent via 4-20mA signals corresponding to 0 to full scale flow of the MFC. Note that these connections DO NOT share a common ground reference. The process value (actual flow achieved) through each MFC is available at the phoenix connector as 0-10 VDC signals representing zero to full flow. The process value signals do share a common ground reference. Cables connected to the 0-10 VDC signals should be shielded with an earth ground connection to the shield at only one end of the cable. The shielding of these cables will reduce the effect of outside electrical noise on the signals to external monitoring equipment. Cable length should be as short as possible to reduce voltage loss due to cable resistance.

Terminal number	Connection
1	MFC 1 negative set point signal (4-20 mA)
2	MFC 1 positive set point signal (4-20 mA)
3	MFC 2 negative set point signal (4-20 mA)
4	MFC 2 positive set point signal (4-20 mA)
5	MFC 3 negative set point signal (4-20 mA)
6	MFC 3 positive set point signal (4-20 mA)
7	MFC 4 negative set point signal (4-20 mA)
8	MFC 4 positive set point signal (4-20 mA)
9	MFC 1 process value (0-10 VDC)
10	MFC 2 process value (0-10 VDC)
11	Common (for process values)
12	Common (for process values)
13	MFC 3 process value (0-10 VDC)
14	MFC 4 process value (0-10 VDC)

E-stop system expansion

The four pin connector at the back of the system is used for e-stop expansion.

Pins 1 and 2 of the connector are an extension of the e-stop device loop. These pins should be jumpered when no additional e-stop devices are connected. Any additional e-stop devices to be added to the loop must be switched output devices with the output contacts closed when the measured levels of the device are within operating limits.

Pins 3 and 4 are connected to a safety relay contact. The contact is open when the system is in an e-stop condition, and closed when the safety system is out of e-stop and reset. This contact can be used as a switch for external devices such as solenoids, lights, alarms etc. This relay output is rated:

Output Rating AC: Inductive AC, 3 A/230 VAC
Output Rating DC: Inductive DC, 2 A/24 V

Gas Connections

Gas connections to the system are shown in the system overview layout pictures (front and back).

Use Swagelok ¼" connectors for all tubing in and out of the system. Take care not to over tighten these connections, as it will reduce the number of times the tube connectors can be used without leakage.

The MFC's have been calibrated with an input pressure of 5 bar. If a higher input pressure is required, the MFC(s) should be re-calibrated to the applicable pressure.

Safety considerations

Operators of this system must fully read and understand this manual.

An integrated E-stop system included with the FCRCGM-03. Tied into this e-stop system is a Watlow LV temperature limit controller. This controller should be enabled when gases controlled through the system are fed to external setups that have the possibility of over temperature conditions requiring fuel flow shutoff. Similarly, the external e-stop loop connection should be connected if there are any setup specific conditions possible that would require gas flow shutoff.

☝ The RS-232 connections to the MFC's bypass the E-stop circuitry. For applications requiring the e-stop system to be enabled, analog control (either local or remote) must be used.

☝ Gases connected to the FCRCGM-03 such as fuels and Oxygen should have a flame arrestor installed at the cylinder.

☝ MFC 3 and it's associated components have been cleaned for Oxygen service. **Do not flow hydrocarbons through MFC 3**. Doing so could damage the sensor element in the MFC.

Check all gas connections for leaks prior to running the system.

System Operation

Gas Type Selection and Correction Factors

Four DB9 connectors are available at the front panel of the system for communication to Bronkhorst EL-Flow MFC's. The EL-Flow series of MFC's is capable of storing up to eight calibration curves for various gases.

Four software programs from Bronkhorst are used to communicate to the MFC's:

FlowDDE: Software tool to establish communications between Windows and an MFC
FlowDDE 2nd: Software tool to establish communications between Windows and an MFC
FlowPlot: Software for monitoring and optimizing digital instruments parameters
FlowView: Software to operate Bronkhorst digital instruments and select gas calibration curves

Connect the appropriate DB9 on the instrument to an x86 Windows based computer using a standard RS-232 extension cable. To select the active calibration curve:

- Establish communications using FlowDDE (or FlowDDE 2nd if FlowDDE is already communicating with another MFC)
- Select the active curve with FlowView. If the desired gas type calibration curve is not listed in flow view, the curve can be added or a gas conversion factor can be applied to estimate actual flow.

Further details about calibration and installing additional gas curves are contained the Maintenance section of this manual. A list of the pre-installed calibration curves for each MFC can be found in the System Specifications section of this manual.

Mass Flow control

Note: The system must be out of E-stop to enable set point signals to be sent to the MFC's in Manual set point control, External analog control, and Flow override modes.

MFCs should never be commanded a set point when source gas is not available or a gas exit path is blocked. These conditions can cause the MFC valve to over heat and lose calibration due to the fact the valve tries to keep opening to get the actual gas flow to meet the set point. To avoid this scenario, always set the flow override switches to the down position (red LEDs lit), and move the switches of only active MFCs to the middle position (orange LEDs lit) when you are ready to flow gas.

Local set point control

To use this function, set the corresponding control switch at the back of the unit to the down position. The Omega process controller will display "MN" indicating that the unit is set for local manual control. Press the up or down arrows on the process controller to adjust the set point.

Finally, set the flow override switch to the middle position. The orange LED will illuminate indicating that the MFC is set for set point control.

External analog control

To use this control type, set the MFC control switch to the up position. The Omega process controller should NOT show "MN". The flow override switch must also be in the middle position with the orange LED lit. The MFC can now be controlled via a 4-20 mA signal connected to the analog signal connector at the back of the system.

See the System Installation – Wiring section of this manual for details on external analog signal connections.

Flow override

Flow override of no flow, or full scale flow is set with the flow override switch to the right of each process controller. This is a three-position switch that will stop gas flow (red LED lit), allow set point control (orange LED lit), or send a full flow command to the MFC (green LED lit).

RS-232 computer control

Computer control using Bronkhorst software is achieved by connecting a PC serial port to the MFC RS-232 connectors located at the front of the machine.

Four software programs from Bronkhorst are used to communicate to the MFC's:

FlowDDE: Software tool to establish communications between Windows and an MFC
FlowDDE 2nd: Software tool to establish communications between Windows and an MFC
FlowPlot: Software for monitoring and optimizing digital instruments parameters
FlowView: Software to operate Bronkhorst digital instruments and select gas calibration curves

Connect the appropriate DB9 on the instrument to an x86 Windows based computer using a standard RS-232 extension cable.

FlowDDE and/or FlowDDE 2nd must be started to establish communications with the MFC(s). FlowView or FlowPlot can then be used to control the MFC's.

Note: Currently the RS-232 connections only support two MFCs at one time from a single computer. Run FlowDDE and FlowDDE 2nd with one instance for each MFC to communicate with two instruments. Bronkhorst may release additional DDE's to support more simultaneous connections in the future. Check www.bronckhorst.com for updates. If more than two MFCs must be controlled via RS-232, it is possible to use two computers, or upgrade the MFC hardware to include a FlowBus communications card.

Note: The MFC Control type is set using FlowView. Setting this parameter to RS-232 will disable analog control through the Omega process controllers. This also bypasses the e-stop circuitry.

Gas source and blending control

Ball valves on the top panel are used to direct inlet and outlet gas streams.

Inlet gases

Each of the four MFC's in the system is connected to a dedicated gas inlet port and a common inlet manifold. This selection between the two inlet sources for each MFC is done via the four ball valves on the left side of the top system panel. If the valve handle is pointing down, the MFC inlet is connected to the common manifold. If the valve handle is pointing up, the MFC inlet is connected it's own inlet port.

Metered gas streams – Straight out or mixed

The four ball valves in the centre of the top panel are used to specify the outlet direction for each MFC, either to the mixed gas manifold, or straight out of the system. If the valve handle is pointing down, the MFC outlet is connected to the common mixed gas manifold. If the valve handle is pointing up, the MFC inlet is connected it's own outlet port. Check valves from each MFC to the mixed line prevent backflow from the mixed gas manifold.

Maintenance

With normal use, no routine maintenance is required. For applications requiring precise flow control, gas flows can be verified using a Molbloc (or similar) flow meter. MFC gas lines may be flushed with clean, dry inert gas.

Troubleshooting

Symptom	Possible Cause	Resolution
No flow when commanded (local set point on Omega process controller(s)	Unit in e-stop	- Check e-stop devices - Pull e-stop button out - Ensure over temp limit switch override is engaged if a thermocouple is not connected. - Reset over-temp limit switch if a thermocouple is connected - Ensure e-stop expansion connector is jumpered if no external e-stop devices are connected. - Press green reset button
	No gas supply to MFC	- Ensure gas is connected with a pressure of 35 PSIG - Check that the gas is connected to the proper inlet port - Check the inlet ball valve is connecting the MFC to the correct inlet port
	Flow override switch is in the wrong position	- Move the flow override switch to the middle position (orange LED will light)
	Excessive back pressure	- Ensure the outlet ball valve is in the correct position to direct flow to the desired outlet port. - Check external gas connections for blockage
	MFC Control Switch is in the wrong position	- Set the MFC control switch to the down position ("MN" will display on MFC)
	Blown MFC fuse	- Replace fuse (400 mA fuse)

	24 VDC power supply failure	- Check 24 VDC power supply fuse.
System will not turn on	No power to electronics	- Plug unit into 115 VAC - Check main power fuse (integrated into power socket on rear panel
Omega process controller(s) not powered	Blown controller fuse(s)	- Replace fuse(s)
Flow override will not force full flow through MFC	10V signal not reaching MFC	- Check 10V regulator board for proper output
	Other	- See "No flow when commanded" symptom in this troubleshooting guide
No flow when commanded (external 4-20 mA set point)	Set point not received by MFC	- Check set point wiring connections on Pheonix connector at rear panel - Ensure hardware used to send set point is functioning properly
	Unit in e-stop	- Check e-stop devices - Pull e-stop button out - Ensure over temp limit switch override is engaged if a thermocouple is not connected. - Reset over-temp limit switch if a thermocouple is connected - Ensure e-stop expansion connector is jumpered if no external e-stop devices are connected. - Press green reset button
	No gas supply to MFC	- Ensure gas is connected with a pressure of 35 PSIG - Check that the gas is connected to the proper inlet port - Check the inlet ball valve is connecting the MFC to the correct inlet port
	Flow override switch is in the wrong position	- Move the flow override switch to the middle position (orange LED will light)
	Excessive back pressure	- Ensure the outlet ball valve is in the correct position to direct flow to the desired outlet port. - Check external gas connections for blockage

	MFC Control Switch is in the wrong position	- Set the MFC control switch to the up position ("MN" will NOT display on MFC)
	Blown MFC fuse	- Replace fuse (400 mA fuse).
	24 VDC power supply failure	- Check 24 VDC power supply fuse.
Flows not at expected values	Incorrect calibration curve loaded on MFC	- Connect to MFC via FlowView and select the proper calibration curve. Note: if the desired calibration curve is not available in the MFC memory, additional curves can be added (up to eight on each MFC). A correction factor can also be applied to estimate actual flow.
	Inlet to outlet pressure difference to small	- A delta P of ??? from inlet to outlet is required for the MFC to operate properly. - Check for sufficient inlet pressure - Check for excessive backpressure
	MFC requires calibration	- Calibrate MFC

Spare Parts

Description	Supplier	Part Number
MFC fuses (Fast 400mA Short UL TE5)	Digi-Key	Digi-Key # WK4340BK-ND Manufacturer # 39504000440
Omega controller fuses (5x20mm GY 250mA)		
24 V power supply fuse (5x20mm GY 2A)		
STi SR-103 safety relay fuse (5x20mm GY 150mA		
Watlow LV series fuse (5x20mm GY 200mA)		
1/3 PSI Check valve	Swagelok	SS-4C-1/3 Note: The #3 gas line is cleaned for O2 service. The part number for the check valve in this line is SS-4C-1/3-SC11

System Specifications

Electrical		
Voltage	110 – 120 VAC 60Hz	
Operating Current Draw (Max)	Approx 3.6A	Inrush could exceed max
Operating Environment		
Temperature	0 to 70 deg C	
Humidity	0 to 90% RH, non-condensing	
Storage temperature	-40 to 85 deg C	
Plumbing		
Tubing material	316 Stainless Steel	
Tubing Size	¼" O.D, 0.035" wall thickness	
Check valves	1/3 PSI cracking pressure	Seal material: Fluorocarbon FKM
Ball valves	0.35 Cv	
MFC's General		
Manufacturer	Bronkhorst	
Model	EL-Flow	
Input pressure Maximum	100 bar	**Calibrated to 5 bar**
Accuracy	±1% FS for ranges > 3ml/min ±2% FS for ranges < 3ml/min	
Warm-up time	30 min. for optimum accuracy 2 min. for ±2% FS	
Plumbing connections	¼" Swagelok compression	
Material (wetted parts)	Stainless steel 316L	
Seals	Viton	
Communication	RS-232, Analog 0-10VDC	Note: Omega process controllers that send external set point to MFCs require 4-20 mA signal in.
MFC 1		
Gas cal. curves pre-loaded		Flow Range
	H2,	500 mls/min
	CO2	500 mls/min
	CO	500 mls/min
	N2	500 mls/min

MFC 2		
Gas cal. curves pre-loaded		Flow Range
	H2,	250 mls/min
	CO2	250 mls/min
	CO	250 mls/min
	N2	250 mls/min
MFC 3		
Gas cal. curves pre-loaded		Flow Range
	O2	100 mls/min
	CO2	100 mls/min
	CO	100 mls/min
MFC 4		
Gas cal. curves pre-loaded		Flow Range
	H2,	50 mls/min
	CH4	50 mls/min
	C2H6	50 mls/min
	C3H8	45 mls/min
	C3H6	50 mls/min
	C2H4`	50 mls/min
Process Controllers		
Manufacturer	Omega	
Model	CN63300-R1-R2-F3-RSP	

Omega Process Controllers

Parameter Settings

Mnemonic	Parameter	Setting
CN63300 Configure Input 1-INP		
tYPE	Input Type	Volt
dCPt	Decimal Point	0.0
rnd	Rounding Element	0.1
FLtr	Digital Filtering	1
dSP1	Display Value #1	0
InP1	Signal Input Value #1	0
dSP2	Display Value #2	MFC 1: 500 MFC 2: 250 MFC 3: 100 MFC 4: 50
InP2	Signal Input Value 2	10
SPLO	Setpoint Lower Limit	0
SPHI	Setpoint Upper Limit	MFC 1: 500 MFC 2: 250 MFC 3: 100 MFC 4: 50
SPrP	Setpoint Ramp Rate	0
InPt	User Input	RSP
CN63300 Configure Output 1-OP		
CYCt	Cycle Time	0
OPAC	Output Control Action	REV
OPLO	Output Lower Limit	0
OPHI	Output Upper Limit	100
OPdP	Output Power Dampening	1
CHYS	ON/OFF Control Hysteresis	0.1
tcod	Auto-Tune Dampening Code	0
ANtP	Linear Output Range	0-10
ANAS	Linear Output Source	SP
ANUt	Linear Output Update Time	0
ANLO	Linear Output Scale Point Low	0
ANHI	Linear Output Scale point High	MFC 1: 500 MFC 2: 250 MFC 3: 100 MFC 4: 50

Configure Lockouts 3-LC		
SP	Access Setpoint	Ent
OP	Access Output Power	LOC
dEv	Access Deviation Display	RED
UdSP	Access Display Units	RED
Code	Access Code Number	2
PId	Access PID Values	LOC
AL	Access Alarm(s) Values	LOC
ALrS	Enable Reset Alarm(s)	LOC
SPSL	Enable Remote/Local Transfer	LOC
trnF	Enable Auto/Man Transfer	LOC
tUNE	Enable Auto-tune	LOC
Configure Alarms 4-AL		
Act1	Alarm 1 Action Mode	b-ot
rSt1	Alarm 1 Reset Mode	Auto
Stb1	Alarm 1 Standby Enabled	yes
AL-1	Alarm 1 Value	MFC 1: 50 MFC 2: 25 MFC 3: 10 MFC 4: 5
Act2	Alarm 2 Action Mode	b-ot
rSt2	Alarm 2 Reset Mode	Auto
Stb2	Alarm 2 Standby Enabled	yes
AL-2	Alarm 2 Value	MFC 1: 550 MFC 2: 225 MFC 3: 110 MFC 4: 55
AHYS	Alarm Hysteresis Value	0.1
Configure Remote Setpoint 7-rS / 7-n2		
dSP1	Remote Setpoint Display Value #1	0
INP1	Remote Setpoint Input Value #1	4
dSP2	Remote Setpoint Display Value #2	MFC 1: 500 MFC 2: 250 MFC 3: 100 MFC 4: 50
INP2	Remote Setpoint Input Value #2	20
FLtr	Remote Setpoint Filter Time Constant	1
bAnd	Remote Setpoint Filter Band	0.5
trnF	Local/Remote Transfer Options	NOR

OEM Documentation

For further information on the components within the FCRCGM-03, consult the following documents and websites:

Document Listing

Component(s)	Document	Website
Bronkhorst MFCs	Bronkhorst Doc. No. 9.17.022O	www.bronkhorst.com
Omega process controllers	CN63100/63300 Series 1/16 DIN Temperature/Process Controllers User's Guide	www.omega.com
Watlow	Watlow Doc. No. 0600-0044-0001 Rev. G Series L User's Manual	www.watlow.com
Sti SR103AM Safety Relay	SR103AM Spec sheet	www.sti.com
24VDC Power supply	Type SPD 60W power supply spec sheet	www.gavazzionline.com
Swagelok components		www.swagelok.com

Notes:

Keep operating and maintenance notes here

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